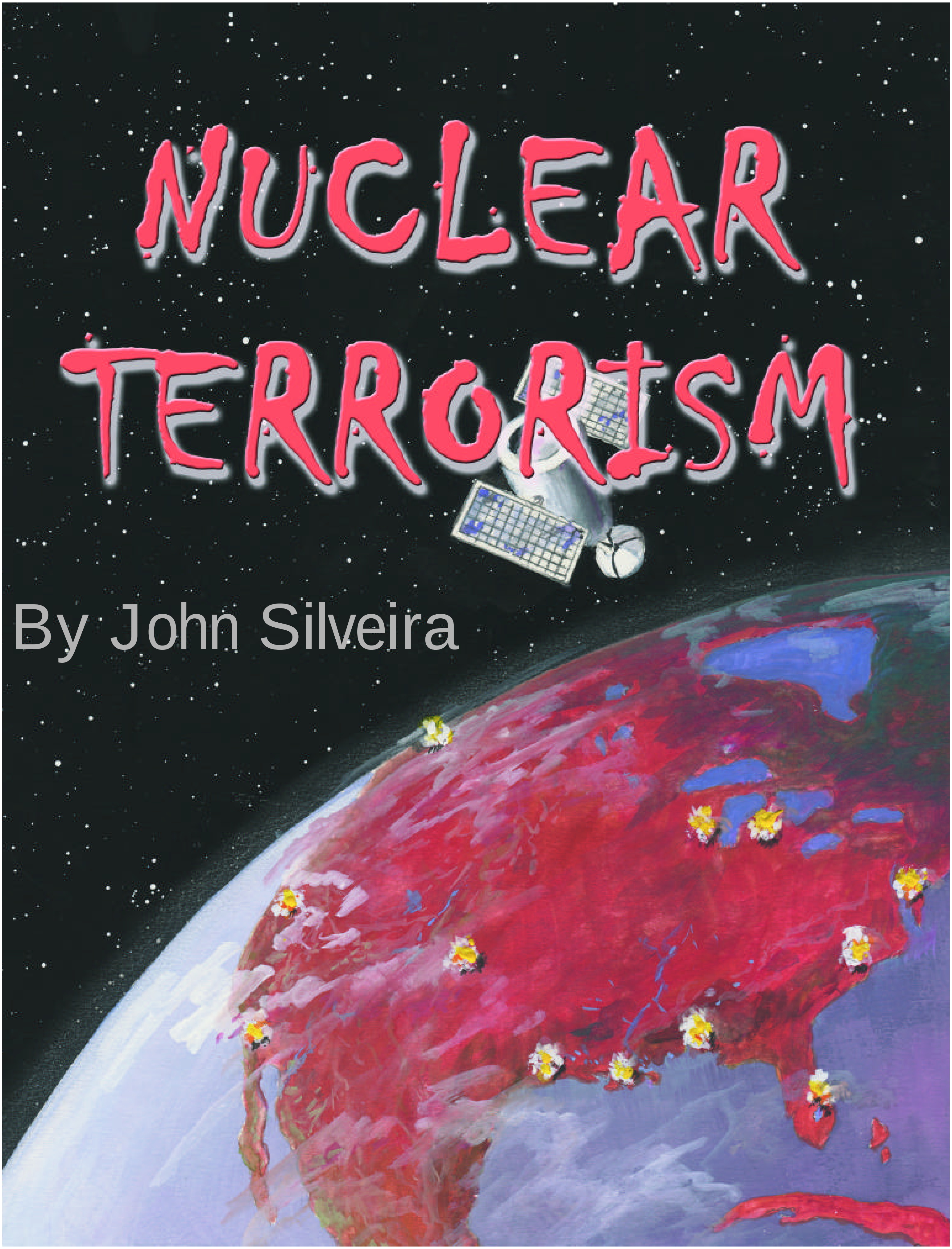
NUCLEAR
TERRORISM
By John Silveira

How the bomb works...
...what happened in Hiroshima and Nagasaki...
...what will happen if terrorists detonate one here...
...how terrorists may get their hands on the bomb

From the events of September 11 we have learned the extent to which terrorists are willing to go to commit an act of terrorism. They are willing to hijack planes and use them as suicide bombs, killing themselves along with thousands of innocents.

It is conceivable that, in the case of Moslem terrorists, the most ardent among them imagine starting a worldwide jihad, or holy war, involving Islam and the West. This, at least, seems to be what Osama bin Laden and his band of thugs, al Qaida, had in mind.

However, the reasons for such terrorist attacks are not part of the scope of this article nor are the solutions, except to say that, though some of our politicians would like us to believe they committed their act of terrorism because of economic envy or a loathing of our freedoms, the fact is that the attacks are a response to American foreign policy in the Middle East and an attempt to force us to change it.

What *is* within the scope of this article is one of the means by which terrorists may one day conduct their attacks, namely, using nuclear bombs.

There is no doubt that the devastating American response to the events of September 11th was not what the terrorists expected. However, our response does not mean that terrorism will go away. On the contrary, because of what many call "the law of unintended consequences," as a result of our decisive response we may find ourselves confronted by even greater acts of sabotage and destruction as terrorists attempt to up the ante in the hope of gaining whatever political, philosophical, or religious objectives they may have.

And that's about all they can hope to achieve. Here in the early part of the 21st century no terrorist organization nor any countries that harbor or sympathize with them could conceivably mount an attack that could "defeat" the United States. We're not going to be invaded. And it's also unlikely that any of the terrorists are acting as they do because they imagine invading us is possible. More likely, they assume that an attack of sufficient magnitude will change American foreign policy into something they find more desirable.

There are possibilities of more terrorist attacks employing more terrifying methods. But it's not likely we will find ourselves enduring random local explosions, the likes of which are used by terrorists in Israel. Ted Kaczynski and Timothy McVeigh notwithstanding, those kinds of sustained bombings require a large domestic terrorist base which isn't yet present in the United States. (This isn't to say there won't be one in the future.)

Up the scale from random bombings is the possibility of biological or chemical terrorism. These attacks are more worrisome than car and truck bombs because an epidemic of small pox or some other disease may become self-sustaining as it sweeps across the country. Dave Duffy addressed the prospects of this kind of terrorism in his *January/February 2001* article titled, *Biological & chemical terrorism*

Definitions:

The words used when talking about "the bomb" are sometimes used interchangeably, though there is some consensus. For example, *atomic bomb* is sometimes used to describe just fission bombs—those that use only uranium or plutonium; other times it's used to refer to both fission bombs and fusion bombs—those that derive most of their power from fusing hydrogen. For this article the words are used as follows:

Atomic bomb — a *fission* bomb, one that derives its power exclusively from the splitting of uranium or plutonium atoms.

Hydrogen bomb — a *fusion* bomb that derives most of its power from the fusing of hydrogen, though all hydrogen bombs are triggered with fission bombs.

Nuclear bomb — the class of bombs that includes both fission bombs and fusion bombs.

Thermonuclear bomb — a hydrogen bomb, so-called because they are triggered by the thermal radiation created by the fission bomb that gets them going.

There are other terms used such as dirty bomb and neutron bomb, but they are explained in the text.

As he points out, the infrastructure required to conduct a biological terrorist campaign may well be beyond the scope of any contemporary terrorist organization or their covert sponsors, and the start of an epidemic may be stemmed by medical aid and sanitary practices which could quickly be put in place.

But at the top of the scale, and the most fearsome of the possible terrorist attacks, is nuclear terrorism. And of all of the acts terrorists may engage in, this is the one that, though it's not likely to bring about the fall of the West, will most likely bring on the utter death of freedom—whether or not it brings on the change in American policy they desire.

And, almost as bad as actual nuclear terrorism, may be just the *threat* of nuclear terrorism. In fact, just trying to prevent such an attack may spell the end of freedom as we know it.

We could lose it all because of some crazy terrorist and a mushroom cloud. And we could lose it forever. We could trade away our rights for the feeling of security. It would be like George Orwell's *1984* where the government has become a dictatorship and justifies it with the excuse that a constant state of war exists.

Types of bombs

With the exception of what are now called "dirty bombs," nuclear terrorism is all about "the bomb." There are several types of nuclear bombs terrorists could employ and several ways they could use them. The bomb types depend on the materials they have available, the technology they have for producing one (if they don't just out-and-out steal one or buy one on the black market), and the size of the explosion they want to make—though there's no doubt that their philosophy will be "the bigger the better."

Militarily speaking, nuclear bombs are classified according to the size of the explosion they create, which determines the military use to which they will be put. The smaller ones are referred to as tactical and the larger ones as strategic.

Tactical bombs, sometimes called battlefield nuclear weapons, are small-yield nuclear devices meant to cause local destruction. Their beauty, from a terrorist's point of view, is that they are small enough (some of them were meant to fit into artillery shells) that some could fit into a suitcase and some may fit into something as small as an attaché case. The smallest bomb made by the United States is called a "Davy Crockett." It's a 0.1K (kiloton) bomb weighing 51 pounds and meant to be fired from a recoilless rifle that could be mounted on a jeep.

The radius of destruction of such a suitcase-size weapon depends on the amount of energy the explosion produces. This is called its "yield." If a single tactical nuclear weapon like this had been brought up to one of the top floors of either of the WTC towers, it would have acted like an airburst (this is the kind of explosion that causes the widest possible area of destruction) that not only would have destroyed both buildings, killing almost everyone in each, but it would have killed most people for a radius of several blocks. Depending on the time of day it was detonated, such a weapon could have killed hundreds of thousands of people.

Similarly, a larger bomb of this type, on the scale of the bombs dropped on Hiroshima and Nagasaki, could be fit into a car as small as a VW Bug, parked several blocks from the White House and Capitol Hill and detonated during the President's State of the Union Address, or some other event, killing most of the heads of our government. Or similarly, it could be flown at a height of two thousand feet over the capital, to effect an airburst, wreaking devastation on the scale of that we wrought at Hiroshima and Nagasaki to conclude World War II.

Strategic bombs, sometimes called "thermonuclear" or "hydrogen" bombs, are more powerful than the atomic bombs dropped on Japan. Thermonuclear bombs are much larger both in the size of the bomb itself and the size of the explosion they create. Some of these devices could destroy entire cities.

It is the actual securing of one and then delivering it that could pose problems. But their use by terrorists can't be completely ruled out.

kilotons *vs.* megatons

The explosive effects of nuclear bombs are so much greater than any of the explosions mankind's weapons had created before that there was little to compare them to. But right from the beginning it was decided to equate them to how much TNT it would take to create as much damage, and it was estimated that the bombs dropped on Hiroshima and Nagasaki were the equivalent of dropping 10,000 to 20,000 *tons* of high explosives—TNT—on each of the cities. It would have taken at least 3,000 of World War II's largest bombers, the B-29s, to drop what the lone B-29, the *Enola Gay*, dropped on Hiroshima. The Greek prefix for thousand is kilo, abbreviated "K," therefore the bomb dropped on Hiroshima was estimated to have the explosive equivalence of 10K to 20K of TNT.

Thermonuclear bombs are thousands of times more powerful than atomic bombs so there equivalence is measured in *millions* of tons. The Greek prefix for million is mega, abbreviated "M."

Several of the countries that currently belong to the "nuclear club" now have bombs (deliverable by missile or bomber) that are more than 1,000 times as powerful as the bombs dropped on Japan.

The differences between atomic and hydrogen bombs is that an atomic bomb depends on fissionable matter, specifically uranium-235 (U^{235}) or plutonium-239 (Pu^{239}) to create an explosion, while a hydrogen bomb has, at its heart, an atomic bomb to get things going, but depends on the fusion of hydrogen into helium to generate most of its power.

The additional materials added to an atomic bomb to make it a hydrogen bomb are cheaper than the uranium and plutonium that go into making the atomic bomb, making hydrogen bombs, pound for pound, cheaper.

Furthermore, there's really no limit to how big of a hydrogen bomb you can build.

Getting a bomb into the U.S.

The most likely way to get one of these bombs into this country would be the same way drugs are brought in: a small plane (especially one landing at a remote airstrip) or a boat.

It is possible that either of these devices, a tactical or strategic nuclear bomb, could be brought into this country by boat, then detonated without off-loading it from the vessel. This was the delivery system suggested in the letter delivered to President Franklin Roosevelt just prior to World War II, and signed by Albert Einstein, in which Roosevelt was urged to embark upon a program to develop nuclear weapons before the Germans did.

Another delivery system could be to detonate a tactical nuclear weapon aboard a low-flying plane. A plane flying low over the heart of a city, or a crowded football stadium, would be guaranteed to kill in the tens if not hundreds of thousands. And if the crew delivering it is willing to die in the process—not an unthinkable scenario after September 11th—a bomb bay door isn't even necessary.

Dirty bombs. At one time this was the designation used solely for describing nuclear bombs that also disperse a large amount of radioactive residue upon exploding. Today it is also used to designate conventional bombs encased in radioactive material.

The blast and fire effects of a conventional "dirty bomb" are the least of such a bomb. There is no nuclear explosion with these devices. The intended effects are the dispersal of radioactive material. But it's unlikely a bomb set off by terrorists could send the material very far, and the number of people affected would be nowhere near the number affected by a real nuclear bomb or even a well dispersed biological agent.

Once such a bomb is detonated our strategy would be to avoid the area of contamination until we effect a cleanup. The real effect of such a bomb would just be terror.

Neutron bombs. These are the bombs that are supposed to kill people but leave property intact. It's worth knowing that *every* nuclear bomb is a neutron bomb, i.e., they all produce neutrons. Ordinarily, however, the radius of the blast is greater than the radius of damage done by the neutrons, so that almost everyone within range of the effects of the neutrons are killed by the blast, anyway.

But in what we today specifically designate a neutron bomb, the bomb is made so as to minimize the blast effects while maximizing the emission of neutrons so that while there is still a nuclear explosion it's much smaller, but the number of neutrons is maximized.

The neutrons can be deadly, depending on how they interact with atoms that make up the cells in your body. Generally speaking someone exposed to a blast of the neutrons doesn't die immediately. Depending on the amount of exposure, death will likely come after a few days as the cells in the body die.

Neutron bombs were designed for the battlefields of Europe where, if Warsaw Pact armies were speeding across West Germany or other countries, whole armies could be destroyed without destroying the countryside in the process. From the war protesters' point of view, they were weapons of greedy capitalists who wanted to kill people while leaving property undamaged. From the the military perspective they were weapons that would kill invading armies while not desolating the entire countryside. People who fled their towns could go home and find much of the infrastructure intact.

How an atomic bomb works

The amount of fissile material (U^{235} or Pu^{239}) typically used to make fission weapons with the yield that destroyed Hiroshima and Nagasaki (about 13 kilotons of TNT) runs from about 6 to 15 pounds of Pu^{239} in a plutonium bomb to about 40 pounds of U^{235} for the uranium bomb. (The U^{235} bomb dropped on Hiroshima required 130 pounds, but that may be because it was the first uranium bomb and therefore more primitive.)

The difference in the amount of fissile material between the Pu^{239} and the U^{235} bombs is because, though the uranium bomb is much easier to set off, uranium is not as efficient at undergoing a chain reaction when it explodes and a great deal of it goes to waste. Approximately as much material undergoes fission in the uranium bomb as in the plutonium bomb, i.e., about 10 pounds, but the rest is just vaporized by the explosion.

This is one of the reasons that "Little Boy," the uranium bomb we dropped on Hiroshima, is, as far as I know, the only uranium bomb this country ever made. All of our other nuclear bombs, whether tactical atomic bombs or the detonators for

hydrogen bombs, have been made from plutonium.

But despite the 6 to 15-pound limit I just gave, smaller bombs are possible. A recent report from the Natural Resources Defense Council states that nuclear weapons with a destructive power of 1 kiloton can be built with not much more that 2 pounds of weapon-grade Pu^{239}, while the smallest amount of Pu^{239} that could be used to achieve critical mass (actually critical density) is about a half a pound.

A bomb using half a pound of Pu^{239} would, naturally, have a yield of less than a kiloton. But the problems of achieving critical density is even more acute with such a small mass and not likely one to be solved by terrorists. It has, however, been solved by scientists in the U.S. and Russia. And that is a problem for us because, as we shall see, there are rumors that very small attaché case-size bombs are missing from the Russian inventory.

The effects of a nuclear detonation

The destructive effects of nuclear explosions are thermal (as in fire), blast, electromagnetic pulse (EMP), and radioactive fallout.

Thermal effects. When a nuclear bomb goes off there is an immediate pulse of x-rays. These x-rays superheat the surrounding air to white hot temperatures. This superheating of the air is the start of the *fireball.* It is also the source of a burst of light and heat that will blind, burn, and cause spontaneous fires. Both the x-rays and the heat will kill. This will all happen in less than one second. Most of the deaths from a nuclear explosion will happen in this first second.

The shock wave. The violent expansion of the superheated air also produces a shock wave—or pressure wave—that radiates out from the fireball at supersonic speeds. The overpressure of this wave knocks buildings down, and throws bodies, automobiles, trucks, and even trains through the air. Many of the deaths and injuries will result from flying debris caused by the shock wave.

And besides the spontaneous fires caused by the searing heat of the initial explosion, more fires yet will be caused by buildings that collapse as the pressure wave passes over them. The source of these secondary fires will be electrical and gas fires caused by buildings that collapse, from utilities that fail, gas stations that are destroyed, and automobiles, trucks, and even gasoline hauling tanker-trucks that are tossed through the air.

The shock wave or overpressure wave will also generate winds whose velocity will depend on the size of the blast and your distance from it. At the very least there will be hurricane-force winds. With a large thermonuclear bomb the winds near the blast will be several hundred miles per hour.

Nuclear fission

There are two ways U^{235} or Pu^{239} can decay. One is by the emission of alpha particles from the nucleus (alpha particles are the same as the nucleus of a helium atom that has been stripped of its two orbiting electrons). What's left behind are other radioactive atoms—protactinium in the case of U^{235}; U^{235} in the case of Pu^{239}—and, once the alpha particle acquires two electrons, there's also a helium atom that didn't exist before.

The other way U^{235} and Pu^{239} can decay is that, on rare occasions, spontaneous *fission* that naturally takes place (the same kind of fission that takes place in an atomic explosion) results in two much smaller atomic nuclei, a *substantial amount* of energy, and two or three free neutrons.

It is this second kind of decay that starts a chain reaction in a fission bomb. In U^{235} if any of those extra neutrons that are produced are absorbed by a neighboring atom of U^{235}, that atom becomes unstable and it undergoes fission and also releases a substantial amount of energy while leaving behind two smaller atoms and two or three extra neutrons. And, if those neutrons are further captured by more U^{235} nuclei...well, you get the picture. More and more neutrons are produced and captured by more and more U^{235} nuclei and this is a chain reaction. First hundreds, then thousands, then millions, then billions, then trillions of nuclei are involved in the reaction, all releasing ever more neutrons and a *huge* amount of energy. And it all happens in a few millionths of a second. A similar but slightly more difficult process must occur to get Pu^{239} to undergo fission.

But, in either case, four conditions must be met:

1) There must be enough of the U^{235} or Pu^{239} atoms to sustain the reaction.
2) The atoms must be close enough together.
3) There can't be too many impurities that can absorb the free neutrons and stop the reaction.
4) The neutrons can't be too fast. (When the nucleus undergoes fission it isn't "exploding" like a pumpkin does when a rifle bullet goes through it. The neutron just goes right through it leaving it more or less undisturbed. The neutron must move slow enough to be "captured" by the nucleus. Then it is more like the "straw that breaks the camel's back" because the extra neutron makes the nucleus unstable and it splits.)

If there aren't enough neighboring U^{235} atoms or they're too far away, the neutrons are lost and the "chain reaction" can't be sustained.

In both Hiroshima and Nagasaki winds as far away as a mile from the center of the blast threw masonry walls as much as 80 feet. If stone walls were tossed about by the winds, it's likely that people were too and the probability of surviving being thrown about in this way is slight.

As to effects of blast pressure on the human body: the human body is remarkably resilient and resistant to just the increase in pressure alone. It's thought that at both Hiroshima and Nagasaki that the people who may have been killed by the pressure increase alone would had to have been within a few hundred feet of the explosion, and they would have been killed by gamma radiation, heat, flying objects, and being thrown by the winds, anyway.

Radiation. In both Hiroshima and Nagasaki there were immediate injuries and deaths from radiation. They were from the ionizing radiation immediately created by the bombs in the first few seconds of the blasts.

For those exposed to the most intense blast of radiation, death was probably 100 percent certain. To lesser degrees this radiation resulted in injuries and illnesses that resulted in varying degrees of temporary hair loss, bleeding—both internal and external—and various other symptoms such as diarrhea. Those who survived more than two months generally recovered to live somewhat normal lives.

For those who serendipitously found themselves behind shielding, such as masonry walls, radiation injuries were minimized in even those victims who were relatively close to ground zero. If you weren't killed by the heat, the blast, flying objects, or fires that erupted after the damned things went off, well, the radiation wasn't a problem.

Other than that, it's thought that if you were ¾ of a mile from ground zero, in either of the Japanese cities, and fully exposed to the effects of the radiation blast, you had a 50 percent chance of living.

Residual radioactivity. Far behind these in importance is going to be residual radioactivity in the form of *fallout*. Elevated death rates due to cancers and birth defects in future years, along with other maladies, may become problems, but they will pale in comparison to the death and destruction that will take place in the first few minutes of a nuclear blast.

And as a historical aside, it's worth noting that both Hiroshima and Nagasaki are bigger and more vibrant cities today than they were before the bombings despite the fact that they were both ground zero for nuclear blasts.

EMP. The very least of the problems from nuclear terrorism will be electromagnetic pulse. All nuclear bombs generate EMP, which is only a danger to electrical equipment, and not a direct danger to humans. And though all nuclear bombs generate EMP, for bombs detonated in the lower atmosphere the range of the EMP is very short and the damage is only local. Really destructive EMP is the result of high-yield bombs detonated at very high altitudes, and this is not likely to be how a terrorist is going to set off a nuclear weapon.

What happened at Hiroshima and Nagasaki

From the two bombs dropped on the Japanese cities of Hiroshima and Nagasaki we have a fair idea of what the effects of the detonation of nuclear bombs in a populated area would be. Both explosions were blasts in the 10 to 20 kiloton range, probably the upper limit of what to expect from a terrorist weapon.

• In those cities everything within about a one-mile radius was totally destroyed, with the exception of reinforced buildings, and even they had doors and windows blown off and were gutted by fires. Flash fires, started by the heat from the blast, started as far as two miles from ground zero in Nagasaki. Heavy damage extended beyond that to a radius of about three miles in both cities.

• Though the two bombs were comparable in size, about four square miles of Hiroshima, directly under the burst, were completely destroyed (this is a circle roughly 2¼ miles across), whereas in Nagasaki the area completely destroyed was about 1½ square miles (a circle about 1¼ miles across). The difference in destruction had more to do with where the bombs exploded and the geography of the cities than with the bombs themselves. Hiroshima is a city that lies in a flat plain, so the effect of the blast traveled unimpeded across the countryside. Nagasaki, on the other hand, is a city of hills so various parts of the city were shielded or shadowed by the hills.

• In both cities all humans and animals within 1 kilometer (about 6/10 mile) of the blast died almost instantaneously.

• From 1 kilometer to about 2 kilometers (1.2 miles), there were still many deaths. Those that died also died almost instantaneously, but many others survived. However, the vast majority of those survivors were injured either seriously or superficially by the blast and heat.

• From 1.2 miles out to a distance of about 2.5 miles many were injured by the intense heat and flying objects.

• At five miles most of the injuries were from flying objects.

In Hiroshima, the layout of the city's buildings, their construction (mostly wood), as well as the flatness of the local terrain conspired to create a firestorm that razed much of the city and contributed to many of the deaths. But Nagasaki, due to its hilly geography and the layout of the city, did not suffer from a firestorm.

In both cities buildings were destroyed by either overpressure waves that resulted from the blast,

fires caused by the heat of the blast, and fires caused by buildings that, though they were beyond the heat effects of the bomb itself, caught fire when they collapsed.

More fires were caused as initial fires spread.

People became casualties as a result of flash burns from the almost instantaneous heat generated by the explosion, the fires caused by the bomb, and blast effects that not only sent bodies flying but turned objects of all sizes into millions of missiles.

What would happen in an American city

Such a bomb, detonated at the proper altitude, in the core of a dense American city could conceivably cause 100,000 deaths and perhaps up to half a million injuries. The totals would depend on:

• the time of day (If set off in a city, people may be at work or at home in the suburbs.)

• the population density (The New York City borough of Manhattan is very dense with 1.4 million people living in 23 square miles. On a weekday, hundreds of thousands more come to the borough from other parts of New York, from New Jersey, and from Connecticut to work. Los Angeles, though it has a population of over 3½ million, is spread out over almost 470 square miles—20 times the area of Manhattan.)

• where the bomb was detonated in the city

• at what altitude (Airbursts are much more destructive than ground bursts, hence a terrorist may set one off near the top of a skyscraper or from a low-flying plane.)

• the nature of the local geography (flat, hilly, etc.)

• the weather (Overcast or foggy weather will cut down the intensity and the range of the thermal radiation from the blast.)

How dangerous are U^{235} and Pu^{239} to terrorists?

The beauty of Pu^{239}, from the terrorist's point of view, is that, though of the 15 or so isotopes of plutonium only two are fissile (capable of being used in a nuclear bomb), the only one that is practical to use in a bomb also happens to be quite safe to handle.

There are four common ways in which radioactive elements decay. One is through fission, which is quite rare. The other three ways are that it can emit alpha particles (which are really just the nuclei of helium atoms that have been stripped of their electrons), positive or negative beta particles (which are positive or negative electrons), or gamma radiation (which is like x-rays). Some elements emit one of these when they decay, others emit a combination of them. There are also other decay particles we're not interested in here, such as neutrinos.

On a scale of how dangerous they are, alpha particles can be stopped by something as thin as paper. In fact, your skin serves as a good barrier to them. Beta particles can be stopped by a window pane. Gamma radiation is the stuff that causes cancer and, in sufficient quantities, can kill you.

Pu^{239} is an alpha particle emitter. You could sleep with it under your pillow. From the terrorist's point of view, the plutonium that he can create the most destruction with is also the safest for him to handle and it can easily be transported by individuals without harm to their persons.

However, the downside of a plutonium bomb is the difficulty of constructing the bomb, of detonating it, and the fact that they are generally encased in U^{238}, which is a gamma emitter which is not safe to handle, and emits radiation which is detectable.

Had terrorists placed a nuclear device in either of the World Trade Center towers, death would have been from the heat, blast effects, and the near instantaneous collapse of both towers. On September 11th, most of the occupants of both towers escaped in the first 10 or 15 minutes, saving tens of thousands. Few, if any, would have escaped from the buildings in a nuclear blast. Many would have died in other buildings, also, but survival would have been more likely due to chance. Most of the deaths would have been from thermal effects and blast. And other buildings in the area, though not immediately destroyed by the blast, would have been destroyed by ensuing fires. Scores would have been gutted and most would have collapsed.

In Hiroshima and Nagasaki, underground bomb shelters with earth-covered roofs, which were directly below the burst, collapsed. But those a half mile away or further survived. From this we can gather that those in subways would probably survive, though collapsing buildings, smoke, and fires could cause problems including the possibility of asphyxiation if raging fires above ground pulled enough air out of the subway system to feed the flames.

Depending on the size of a terrorist's bomb, surrounding skyscrapers may be pushed over. Most likely, however, those not near the blast would not fall immediately, though deaths and injuries within them would be extensive. Most of the damage would come from fires caused by the intense heat from the blast and secondary fires that come from short circuits and other things. Some of those buildings would eventually collapse due to fires, and most of those left standing would be damaged beyond repair.

Unlike being near ground zero, where (unless you're in a subway) death will be instantaneous and

U^{235} *vs.* Pu^{239}

There are reasons the United States and other developed countries use Pu^{239} as opposed to U^{235} in their bombs. But the main reasons are, first, that U^{235} is a naturally occurring element that is very rare while Pu^{239} is man-made element made by subjecting more plentiful U^{238}, the most common occurring isotope of uranium, to neutrons in nuclear reactors. Until the end of the Cold War, the United States made tons of Pu^{239} this way every year. The second reason is that, while Pu^{239} is harder to detonate in a bomb, once you start the fission, it undergoes the fission process much more efficiently, consuming more of the Pu^{239} in the process. A U^{235} bomb, on the other hand, is easier to get going, but the fission process is very inefficient and about 90 percent of the uranium is wasted.

The third reason is that, since bombs can be built with much less Pu^{239} than with U^{235}, the bombs themselves are lighter and missiles that carry them have longer ranges.

But there are also reasons why developing countries initially build U^{235} as opposed to Pu^{239} bombs. It is because, although U^{235} is rare, to manufacture Pu^{239} you must have a type of nuclear reactor called a "breeder reactor." In this kind of reactor you can literally actually produce more fuel than you are consuming by irradiating U^{238} with neutrons to create Pu^{239}. If you don't have a breeder reactor, and few countries do, you can't make Pu^{239}.

A second reason is that the triggering device in a U^{235} bomb can be quite crude. All you need to do is get enough of it in one place and BOOM. It's as if U^{235} is just dying to go off. But the triggering device in a Pu^{239} bomb is a technological marvel in and of itself. Neutron emitting isotopes of beryllium and polonium are introduced to enhance the production of neutrons required for fission, and the Pu^{239} core must be surrounded by a layer of explosives (usually 32 separate little bombs) to be imploded precisely.

almost certain, a few blocks away your fate may be the result of dumb luck—good or bad. The further away you are from a blast, the more likely your fate will be tied to shielding or "shadowing" from neighboring buildings. It's quite likely that within a few blocks of such a blast there will be people who survive unscathed while people near them will be injured or killed by debris. And, most certainly, those shielded by buildings will not suffer the effects of ionizing radiation.

Those exposed to the light from the blast may be burned on only one side. In Hiroshima and Nagasaki, whether someone was burned through their clothes sometimes depended solely on the colors of the clothing they wore. Some people were badly burned through dark colored clothes while others standing next to them but wearing white clothing were relatively unscathed. Others wearing various colors of clothes found themselves burned in patterns that corresponded with the various lightness and darkness in the patterns of their clothes. In the meantime, even the way clothes fit determined how burns were dispersed. Tight fits tended to burn more than loose fits.

Given today's synthetic fabrics, it's conceivable that some people would find dark clothes melted into their skin from acrylics and such while the rest of their bodies will be relatively unscathed.

Different American cities, if targeted by nuclear terrorists, would suffer different effects. An airburst over Los Angeles, for example, may see destruction over vast amounts of the city with numerous pockets that are relatively unscathed because of the numerous hills and valleys in that city.

In both Hiroshima and Nagasaki most underground utilities were undisturbed by the blast because it was an airburst. Where there were breaks, it was due to collapsing buildings. However, aboveground utilities, such as power and phone lines, were damaged or destroyed depending on how close they were to the burst.

In American cites, where many of the utilities are underground, a surprising number would probably remain in service. In areas where large buildings collapsed, such as on Manhattan, losses in service would probably be local.

Within minutes after a nuclear detonation, the biggest threats to human life will be fire and collapsing buildings. On September 11th most of the victims died in the collapse of the towers. But we know from World War II that it is possible for whole cities to burn in a firestorm. While Hiroshima burned in a firestorm, Nagasaki did not. It was one of the reasons Hiroshima suffered more casualties than Nagasaki. Other cities, like Dresden, Germany, though they didn't suffer a nuclear detonation, also burned in firestorms.

A firestorm is usually the result of many smaller fires coalescing into one huge fire which causes an updraft so severe that it sucks air in from all sides. The air rushing in often has gale-force winds that prevent the fire from spreading. But the inrushing winds continue to feed oxygen to the flames, and if strong enough make it difficult or impossible for those who have been injured to leave the area. Such a fire continues to burn until it consumes everything within the flames.

Whether or not an American city that was subjected to a terrorist nuclear attack would be ravaged by a firestorm will depend on the weather,

The power in a 1-kiloton bomb

To give you an idea of how much explosive force a one kiloton bomb has, each of the Boeing 767s that flew into the World Trade Center carried no more than 70 tons of fuel. A one-kiloton bomb explodes with the energy of about 14 fully-loaded 767s crashing. And because the one-kiloton bomb releases its energy faster, its explosive characteristics are enhanced. (Think of this as comparing the energy released from a tankful of gasoline over a week's driving as opposed to how the same energy would be released if the same tankful were consumed in a hundredth of a second. In the former case we have a week of pleasant driving; in the latter we have a gigantic explosion that would level your home, all from the same tankful of gasoline. Yet, it's the same amount of energy being released.)

A one-kiloton bomb exploding at the top of a skyscraper or in a small plane 500 to 1,000 feet above a crowded city could, depending on the geography and population density of the city, result in tens of thousands, if not hundreds of thousands, of deaths.

To get a larger radius of destruction you must increase the yield of the bomb. The radius of destruction increases roughly as the cube of the bomb's yield, so to get a radius of destruction twice as great as the Hiroshima blast, which was equivalent to 13 kilotons (13K) of TNT, the bomb would have to be about eight times more powerful, or about 100 kilotons. (Incidentally, estimates of both the Hiroshima and Nagasaki blast have run from 10K to 20K, depending on who's doing the estimating. I've settled on 13K for this column.)

the layout of the city and the composition of its buildings, other sources of combustible materials such as gasoline storage, and the size of the bomb itself. In most American cites a firestorm would be possible.

How do you keep yourself safe?

You don't.

Kevlar vests aren't going to save you if you're too close to an exploding nuclear bomb, and if you are downwind from the fallout, neither will lead underwear. As in lightning storms, the real defense is just not being close to a target. Figuratively speaking, you don't want to stand under the trees.

Other than just not being too close to ground zero, there is a pill you can take—a potassium iodide (KI) or a potassium iodate (KIO_3) pill. One of the effects of a nuclear detonation is the creation of a short-lived radioactive isotope of iodine, that is quickly absorbed by the thyroid gland.

As this particular isotope (I^{131}), with its half-life of roughly eight days, degrades, it causes potentially fatal damage (including cancer) to your thyroid gland. If you are downwind from the fallout you may be affected.

What the pill does is flood your body with iodine so it doesn't absorb any more. This blocks the absorption of the radioactive isotope. Within a few months the radioactive iodine will have disappeared from the environment because of its short half-life.

Where terrorists may get a bomb

To get a bomb terrorists will either have to:

- get one already assembled
- get the parts for one and assemble it
- build one from scratch

All are possible, but it's just that some are more likely than others, and, of course, it's possible that they would get some parts prefabricated and have to make other parts from scratch. But no matter how they come up with a bomb, it would seem that they're going to have to have help from someone who's already done it.

There are unsubstantiated (and likely untrue) rumors that Osama bin Laden bought several of these suitcase-sized bombs for $30 million and two tons of Afghan heroin. But Jamal Ahmad al-Fadl, a Sudan native and one-time bin Laden associate, testified in the 1993 WTC bombing trial that bin Laden had unsuccessfully tried to obtain uranium suitable for building a bomb for $1.5 million.

The point is there are terrorists who are trying to obtain the material (U^{235}) to make a basic uranium bomb, which they probably could assemble, or to buy a stolen or smuggled plutonium bomb already assembled.

The so-called "nuclear club" is made up of just nine members. Following each name is the date they detonated their first nuclear device:

- **U.S.** (1945)
- **U.S.S.R.**—now **Russia** (1949)
- **United Kingdom** (1952)
- **France** (1960)
- **China** (1964)
- **India** (1974)
- **Pakistan** (1998)

Israel and the **Union of South Africa** have no doubt built bombs, and may even have detonated one, but South Africa claims to have left the club.

Israel had its first nuclear reactor in the 1960s and began building its own bombs in 1968. No one is really sure just how many they have, but it's likely they are building three to five each year.

When the Yom Kippur War started, catching the Israelis by surprise on October 6, 1973, Israeli positions were overrun all along its borders. The United States had already stopped supplying them with arms because of their stand on nukes. However, on October 9th, Israel notified then Secretary of State Henry

Kissinger of its readiness to use its nuclear weapons if Israel's fortunes got worse. The United States reopened the supply lines that day and Israel turned back the invasion.

It is thought today the Israelis have between 80 and 150 weapons. But at this point in time none of them are considered to pose a terrorist threat to the United States.

For a terrorist to get the bomb in the foreseeable future it would seem as though at least one of the countries in the nuclear club would have to be involved.

Russia. When the former Soviet Union began to disassemble, one of the first concerns was what was going to happen with all of its nuclear weapons? They had between 13,000 and 15,000 strategic nuclear warheads and another 30,000 to 40,000 tactical nuclear warheads in their arsenal.

All the Soviet's strategic weapons were concentrated in Russia, Ukraine, Kazakhstan, and Byelorussia, and the tactical weapons were just in Russia, Ukraine, and Byelorussia. With the breakup the Russians intended to pull *all* of the nuclear weapons back behind their own borders and we can only hope they kept track of them all.

But there were several complications. One is that Russia has fallen on difficult economic times and the military arsenal they once held represents one of the few hard cash exports that can be readily sold for Western currency. An individual or group could make one or two of the 50,000 bombs "get lost" during the accounting and try to use them to strike it rich.

In September 1997 *60 Minutes* ran a story in which former Russian National Security Adviser Aleksandr Lebed claimed the Russian military had lost track of more than 100 suitcase-sized nuclear bombs. The bombs are supposed to be roughly 24 by 16 by 8 inches. The Russians reject this claim, as do many American intelligence experts.

How a thermonuclear bomb works

A thermonuclear (or hydrogen) bomb is triggered by first setting off a "conventional" atomic bomb. Though there are several variations on how a specific bomb is made, in principle here's how one works:

The atomic bomb is made with a hollow sphere of Pu^{239}. At the center of this sphere is a heavy isotope of hydrogen called tritium (H^3). The Pu^{239} is encased in a layer of lithium deuteride. The neutrons from the exploding Pu^{239} compress the H^3 and begin fusing it. The combination of fissioning Pu^{239} and fusing H^3 turn the lithium deuteride into a mixture of another isotope of hydrogen, deuterium (H^2), and H^3. The extreme heat from the fissioning Pu^{239}, which now exceeds 100 million degrees, forces the H^2 and H^3 to fuse together and create helium. It is this fusing of hydrogen at the center of the sun that makes the sun shine, and in a thermonuclear bomb it is this same fusing that creates an even more fearsome explosion than an ordinary atomic bomb.

Very often, the outer casing that contains the thermonuclear bomb is made from the more commonly found isotope of uranium, U^{238}. Neutrons released by the fusing deuterium and tritium also create extra neutrons. These are high energy neutrons and not the type used to split Pu^{239} or U^{235} nuclei. They will, however, split U^{238} nuclei and this fission produces even more energy.

Thermonuclear bombs can typically be made hundreds and even thousands of times more powerful than atomic bombs.

But just as Pu^{239} bombs are more difficult to make than U^{235} bombs, thermonuclear bombs are more difficult to make than Pu^{239} bombs. However, once you perfect the method of making a thermonuclear bomb, it is easier to make bigger and bigger ones than it is to make bigger and bigger uranium or plutonium bombs. It's also cheaper.

The consolation is that thermonuclear bombs are currently beyond the technology of what terrorists are capable of and may remain that way for some time. However, stealing them is not. And it is also conceivable that if some third world country does make one, they could supply one to a terrorist group.

Delivery of such a weapon to its intended target then becomes a problem, but because it is larger, the bomb doesn't have to be nearly as close. Such a bomb, if large enough, could be detonated while still on a boat in a harbor or while resting in the back of large truck, or even flown in a chartered plane. It would, for all practical purposes destroy a city.

But that brings about another aspect of the problem. Even if all the bombs can be accounted for, there are thousands of scientists and technicians who worked on the Soviet nuclear programs. They've become unemployed in their own homelands. They need jobs, they can build a bomb from scratch, and there are people who'll pay them to do it.

There was an estimated 100,000 scientists and technicians involved in the Soviet nuclear weapons programs, including 3,000 who had the highest levels of expertise. Now quite a few of them are out of work and the ones who have jobs are getting paid in worthless rubles.

Since the end of the Cold War, there have been at least 175 detected attempts to get plutonium out of Russia, either by smuggle or direct theft. There's no way to know whether any, which may have gone unreported, have succeeded.

But in 1994 three batches, amounting to a bit more than 12-ounces, of weapons grade plutonium (Pu-239)

were seized in Germany. Theoretically, a bomb could be made from this amount. The good news is that its yield would be considerably less than a kiloton and not something that would impress an Air Force general in the Strategic Air Command. The bad news is that the havoc it would have caused would have been greater than that of the two planes that hit the World Trade Center. In fact, it's very unlikely that many of the people who were in either of those buildings could have survived the detonation of such a device.

The plutonium's source was immediately traced back to Russian nuclear weapons facilities.

Pakistan, which is roughly 97 percent Muslim, has the bomb. Apparently it has made its bombs from U^{235} using what is called the "centrifuge enrichment" method.

The difficulty is in acquiring a suitable centrifuge, and because of problems in balancing such a centrifuge properly this has proved to be difficult or impossible for all but the most technologically advanced countries. To get around this, the Pakistanis simply stole the plans for such a centrifuge.

In 1997, Pakistan detonated six atomic bombs. It's thought that the sixth and last may not have been a uranium bomb, as all the earlier ones were, but may instead have been a plutonium bomb. If it was, it means either Pakistan is now making its own plutonium at a nuclear reactor in Khushab, in the Punjab province, or it found a source of Pu^{239} from abroad.

Neither scenario is good. In the first, if Pakistan can manufacture its own Pu^{239}, though the country is stable today there's no way to know which way that nation will go tomorrow and one day they could surreptitiously become a supplier of the metal to terrorist groups. There are already extreme Islamic groups in Pakistan, and many of the Taliban volunteers came from Pakistan.

In the second scenario, if they purchased plutonium from abroad, it would seem apparent that so can others, including terrorist groups.

It's also thought that the same reactor at Khushab may be capable of creating tritium, one of the ingredients for a hydrogen bomb. If that's the case, then the stability of Pakistan may be one of the prime goals for the early 21st century.

The problem is not just that Pakistan's political picture could change, but it's more apt to have individuals sympathetic to the idea of jihad who may be willing to steal or smuggle a bomb out of the country. Of course, with probably no more than a hundred bombs, so far, they are probably much easier to keep track of than the tens of thousands the Russians have.

India. India detonated its first atomic bomb back in 1974. With tensions building between it and Pakistan growing, it detonated another six in 1998. India claims that one of the bombs it detonated in 1998 was a low-yield thermonuclear bomb.

India is, at this time, one of the countries less likely to supply a terrorist group with a nuclear weapon. But theft cannot be discounted.

Iraq. In 1976 Iraq bought the Osiraq research reactor from the French. It was constructed outside of Iraq's capital, Baghdad. Its supposed purpose was as a reactor for making radioactive isotopes. In 1980 Iraq tried to buy 25,000 pounds of depleted uranium. This is the stuff you use to make plutonium (the bomb), not medical grade isotopes.

This was enough for the Israelis. In 1981 the Israelis flew American-made aircraft, F-16s, and in less than two minutes of bombing they leveled the reactor.

Other countries, such as the United States, the United Kingdom, France, China, Israel, and South Africa are low on the list of countries who may supply a terrorist group with an assembled bomb or the expertise to make one. But there is always the possibility of one being stolen, or of people with the expertise to build a crude one selling that expertise to the highest bidder on the black market. People have done stranger things for money.

The first three bombs

The very first atomic bomb exploded was a plutonium bomb nicknamed Gadget. It was detonated at the Trinity Test Site on what is now the White Sands Missile Test Range in New Mexico.

Little Boy is a uranium bomb that weighed about 9,700 pounds and dropped on Hiroshima. It exploded 1,800 feet above the ground.

Fat Man was a plutonium bomb weighing about 10,000 pounds and dropped on Nagasaki. It exploded 1,650 feet above the ground.

The yield of all three bombs are estimated to have been in the 10 to 20 kiloton range.

Can terrorists develop one themselves?

The problems with terrorists actually building a nuclear bomb themselves are manyfold. The first is just getting the overall expertise to do it. This isn't something that some backyard tinkerer is going to do in his garage.

Procuring the fissionable material itself may be the least of the problem. As I said, the Germans intercepted Russian plutonium already.

Other than purifying uranium or plutonium to get weapon-grade material, making a detonator for a plutonium bomb may be the most difficult part of employing a nuclear bomb. This isn't just a matter of lighting a fuse and standing back. One of the challenges for scientists working on the Manhattan Project, America's atomic bomb project during World

War II, was making a trigger for a plutonium bomb. Detonators for them are really high-tech stuff. Unfortunately, making a trigger for a uranium bomb is easier. If they had enough U^{235} to fashion a bomb, they could probably make the trigger in a cave in Afghanistan.

A few years ago a shipment of detonators being sent to Iraq was intercepted. Making a detonator for a plutonium bomb was one part that even their best scientists didn't want to tackle.

Testing to ensure they are manufacturing a working bomb is a problem. Testing one is difficult to hide, even if the test is an underground test, as even they have a characteristic seismic signature that differs from that of earthquakes, volcanoes, and other natural phenomena.

What can we do?

Detection of nuclear weapons on American soil requires both intelligence and technology.

The upside is that there are better and better detection methods for finding nuclear weapons terrorists may have, and using these gadgets are not intrusive in the way that many of the federal government's solutions to combating terrorism are. They are not likely to infringe on the one thing that makes Americans unique: our freedoms. The way some of them work is that fissionable materials that make nuclear bombs work emit a certain spectrum of gamma radiation that proper equipment can detect, often at quite a distance.

U^{235} and Pu^{239} are themselves very difficult to detect, because they emit only alpha particles which are very short range and easy to shield from detection. However, batches of U^{235} and Pu^{239} are never pure but often have other radioactive elements in them that are gamma emitters. Gamma radiation is very difficult to hide. Along with the impurities, the products U^{235} and Pu^{239} decay into are also radioactive and can be detected. For example, one of the decay byproducts of U^{235} is protactinium-231 (Pa^{231}) which, when it decays, emits alpha, beta, and gamma radiation. The gamma radiation is detectable. With equipment that is sensitive enough, this kind of radiation is detectable even with equipment carried on aircraft over a city.

One of the ways "prospectors" looked for uranium in the '50s and '60s was by flying over wide stretches of the American West carrying Geiger counters "tuned" to the narrow spectrum of gamma radiation emitted by certain radioactive elements.

Also, the detonation of nuclear devices are started using conventional explosives. More and more, conventional explosives are also detectable using modern equipment. And, once again, this kind of equipment doesn't seem to pose problems by tampering with our freedoms.

The downside is that these detectors, for either radioactive materials or conventional explosives, are not yet widespread.

The President wants to install a $25 billion Anti-Ballistic Missile (ABM) System as a defense against missiles being launched by rogue countries or terrorists who somehow secure ballistic missile capability. The problem is that no banana republic is likely to strike at the United States in this manner and, within a few years, such a system is likely to be obsolete anyway.

Far more effective would be money spent on good intelligence and the latest detection technology for the Nuclear Emergency Search Teams (NEST), a little known and somewhat secret agency established in 1975 under the Department of Energy. NEST's task is to search, locate, and identify devices or material that may be nuclear bombs. Though its personnel have been called out on numerous occasions, as far as the public knows, they have never found a nuclear bomb. And given the complexities of making a bomb, it's probably an accurate assessment.

Currently working on a budget of about $100 million a year, which is less than ½ percent of that projected to build an ABM system, NEST is the only realistic safeguard we currently have against terrorist nukes. In the opinion of this writer, NEST is grossly underfunded and, in light of September 11th, it is where this country should seriously consider placing more emphasis. Δ